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I-20135 Milano (IT)(54) **Bonding apparatus for semiconductor electronic devices.**

(57) The bonding apparatus is useful to form electric connections between predetermined bonding pads (A) of semiconductor electronic devices (D) and respective electric contact leads (L) formed on a frame (T) holding the devices (D) in tidy arrangement. It comprises a supporting structure (2), means of advancing the frame (T) along a longitudinal direction (X) in a work plane (3) on the supporting structure (2), a bonding head (4), and a high-precision X-Y table (5) carrying the bonding head (4) for accurately setting the bonding head (4) in the work plane (3). The bonding apparatus further comprises a carriage (10) guided on the supporting structure (2) for movement in a transverse direction (Y) to the longitudinal direction (X), the X-Y table (5) being mounted on said carriage (10).

The bonding head working range always spans a sufficiently large area for a single device, thereby enabling connections to be made even when the side-by-side devices are arranged in two or more rows.

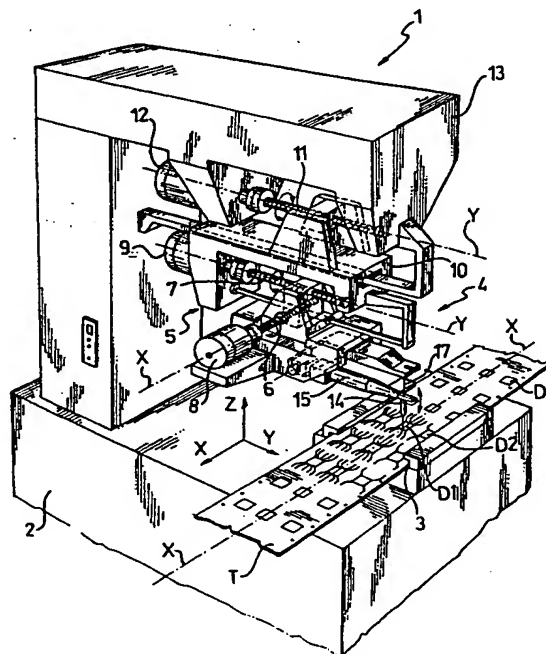


FIG.1.

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This invention relates to a bonding apparatus for forming electric connections between predetermined bonding pads of semiconductor electronic devices and respective electric contact leads formed on a frame in which the devices have been tidily arranged.

In the manufacture of semiconductor electronic devices, the electronic device proper (i.e. a piece of suitably doped silicon, sometimes referred to as die) must be provided with leads for setting up electric contacts. Each of the leads must be connected electrically to a definite area of the silicon.

To this aim, the silicon piece is placed securely onto a very thin metal frame, which frame is, among others, formed with sections that are eventually to be fashioned (as by appropriate blanking) into the leads of the device.

The electric connection between each of the leads and each of the silicon pads is made by depositing a wire conductor and bonding it to both the silicon and the lead. Typically, the bonding wire is made of gold, and bonding is a ultrasonic process.

This operation, although conceptually simple, is made highly critical by the minute size of the connections to be formed and their large number; a typical such number would be a few hundred connections spread over the perimeter of a square measuring less than 2 cm along the side. Notice that the acceptable margin for error is almost nil, because a single faulty bond out of the hundreds made on one device would turn the whole device into a reject. Further, the time taken to carry out all the bonds should be the shortest possible if large production volumes are sought.

Bonding is performed by a head mounted on an X-Y table, that is a mechanism which can be moved in a plane controllably along two spatial coordinates, X and Y in fact. Tables are known which, while ensuring the necessary high degree of accuracy, can work at extremely fast rates on the order of 100-200 ms per connection, including bonding to the silicon, depositing the wire, bonding to the lead, and cutting the wire. Tables of this type will be referred to as very high precision tables hereinafter.

Once the connections have been made on a device, the frame is indexed forward far enough to bring the next device to be made with connections within reach of the bonding head.

The metal frame accommodates, in fact, a set of identical electronic devices lined up one behind another. Upon completion of the connections on a given number of the devices, the whole batch is transferred to the next processing step, wherein an insulating resin is poured over the devices to encapsulate the leads. Notice that the frame may either be a definite length or in the form of a

flexible strip, stored on a purposely provided reel, which is fed forward continuously and cut at intervals.

The resin pouring step takes a fairly long time, for both pouring and curing the material, and is often found to be the bottleneck of the whole process.

Therefore, frames have been developed wherein the devices can be lined up into two columns instead of one.

If the device size is very small (less than one centimeter), conventional machines can handle pairs of side-by-side devices without undue difficulty.

With larger size devices, however, the processing head must be slowed down to avoid that the larger working area to be spanned may degrade accuracy to an unacceptable extent. This reduced speed frequently is enough to thwart any advantage gained in the pouring step, and accordingly, it is common for the paired device setup to be forgone.

The underlying problem of this invention is to enable several electronic devices, laid side-by-side in a frame, to be bonded while retaining a processing rate and a degree of accuracy which are comparable with those to be obtained when the devices are arranged in a single column.

This problem is solved, according to the invention, by a bonding apparatus for forming electric connections between predetermined bonding pads of semiconductor electronic devices and respective contact leads formed on a frame in which the devices have been tidily arranged, comprising a supporting structure, means of advancing the frame along a longitudinal direction in a work plane on the supporting structure, a bonding head, a high-precision X-Y table carrying the bonding head for accurately setting the bonding head in the work plane, characterized in that it further comprises a carriage driven in a guided fashion across the supporting structure in a transverse direction to the longitudinal direction, the X-Y table being mounted on said carriage.

In this apparatus, the bonding head operates at all times within a working range sized for a single device. To make the connections on plural electronic devices laid side-by-side, the bonding head is bodily shifted with the carriage such that its working range will encompass the area occupied by a device to be bonded, each time.

Using this apparatus, connections can be made even on two or more rows of side-by-side devices.

As may be appreciated, moving the carriage to shift the X-Y table, and the working range of the bonding head with it, is not so critical as moving the X-Y table itself, a comparatively coarse setting being all that is required.

In order to maximize the working range in the transverse direction, and hence the number of the side-by-side devices that can be processed, the carriage is suspended, of preference, from a portion of the supporting structure which overlies the frame, and better still, the X-Y table is in turn suspended from the carriage.

In this way, a compact construction can be provided, in the sense that the bonding head need not include extra-long reach arms which might create problems from mechanical inertia.

The bonding head may be any of several types. Advantageously, it includes a tubular bond bit, a feed channel inside the bond bit, a bonding wire to be fed through the feed channel, elevating means for shifting the bond bit vertically and pressing it onto the bonding pads and the leads, and means of imparting ultrasonic vibrations to the bond bit.

The elevating means may also be any of several types; for example, in a preferred embodiment, they may comprise a swing arm pivoted to the bonding head and movable in a vertical plane, the bond bit being mounted on one end of the swing arm.

Further features and advantages of an apparatus according to the invention will be more clearly apparent from the following description of a preferred embodiment thereof, to be taken in conjunction with the accompanying drawings, in which:

Figure 1 is a perspective view showing schematically an apparatus according to the invention; and

Figures 2 to 8 illustrate, in schematic form, the successive steps of depositing a wire conductor.

In the drawing figures, generally shown at 1 is a bonding apparatus which comprises a supporting structure 2 having a work surface 3 formed thereon. Three orthogonal axes X, Y and Z are defined on the structure 2, with the work surface extending along the X and Y axes and Z representing the vertical direction.

Located on the work surface 3 is a frame T on which electronic devices D are arranged. The electronic devices D are tidily arranged on the frame T, into columns lying along the X direction and rows lying along the Y direction. The frame T is advanced across the work surface 3 along the X direction by conventional means, not shown. The X direction will be also referred to herein as the longitudinal direction, and the Y direction as the transverse direction, relative to the direction of advance of the frame T.

The structure 2 carries, located above the work surface 3, a bonding head, generally denoted by 4, which is mounted on an X-Y table 5. The X-Y table 5 is a very high-precision one which includes drive means for movement in the X and Y directions; in

the example shown, such means comprise respective worm screw drives 6 and 7 rotated by respective electric motors 8 and 9. The X-Y table 5 will be neither described nor illustrated in detail because known per se.

The X-Y table 5 is not mounted directly on the structure 2, but rather on a carriage 10 which is guided for movement along the axis Y on the structure 2. For this purpose, the carriage 10 is provided with a worm screw mechanism 11 and an electric motor 12. The carriage 10 is mounted under a bracket 13 of the structure 2, and the X-Y table 5 is mounted under the carriage 10. Thus, the bonding head 4 is substantially a suspended one.

The bonding head 4 further comprises, in a conventional manner, a substantially tubular bond bit 14 having a feed channel 15 formed therein which is terminated with an outlet 16.

A bonding wire 17 of gold is fed through the channel 15. The bond bit 14 is mounted on the top end of a swing arm 18 pivoted to the bonding head 4 and movable in a vertical plane. An elevating means (not shown) drives the arm 18 to produce movement of the bond bit 14 substantially in the same direction as the Z axis. Another means (not shown) is provided on the bonding head 4 for imparting ultrasonic vibration to the bond bit 14 and cause the wire 17 to form a bonded joint.

The operation of the apparatus 1 proceeds in a cyclic manner through the steps described herein below.

With the frame T held stationary on the work surface 3, and the carriage 10 stationary on the structure 2, the working range of the bonding head 4 encompasses a selected electronic device D1 on which bonds are to be carried out. The X-Y table 5 moves the bonding head 4 horizontally, whereas the elevating means moves the bond bit 14 vertically on the bonding head 4.

On completion of all the bonded connections on the device D1, the motor 12 is operated to drive the carriage 10 such that the working range of the bonding head 4 can be shifted to span a device D2 located in the same row as the device D1 but in a different column. Once the bonded connections on the device D2 are completed, the bonding head is moved to the next device, and so on until a whole row of devices D is served. Thereafter, the frame T is advanced to bring under another row.

The bonding operations are performed on a single device D in a conventional way. However, it may be appropriate to briefly review such operations for clarity, making reference to Figures 2 to 8 of the drawings.

During a first step (Figure 2), the wire 17, being passed through the bond bit 14, is formed with an end enlargement, shown at 17a, and brought to a bonding pad A provided on the electronic device D.

The enlargement 17a is then pressed (Figure 3) onto the bonding pad A, while the bond bit 14 is imparted ultrasonic vibration, thereby the wire 17 becomes bonded to the pad A.

The bond bit is then raised while letting the wire 17, still attached to the device D, run free through the feed channel 15 (Figure 4).

Again with the wire 17 movement unrestrained, the X-Y table 5 is then moved to bring (Figure 5) the bond bit 14 above a lead L to which the bonded pad A is to be connected electrically.

The bond bit 14 is then lowered and pressed onto the lead L (Figure 6). The combined action of the pressure on the wire 17 from the outlet 16 and of an ultrasonic vibration imparted to the bond bit 14 will produce the bond.

Then, the bond bit 14 is raised somewhat with the wire 17, now attached to the device D, free to run through the feed channel 15 (Figure 7), whereafter the wire 17 mobility is checked and, consequently, the wire itself will be pulled apart at the location of the bonded joint just completed.

Finally (Figure 8), the bond bit 14 with the wire 17 leftover from the pulling apart is pressed onto a special tool 19 to reform the enlargement 17a and a fresh bonding cycle commenced.

As previously mentioned, the above cycle is completed in a very short time, usually within 100 to 200 ms. Evident is, therefore, that the drive to the X-Y table 5 is a highly critical one and the reason why it has been heretofore impossible to work on frames with more than one column of side-by-side electronic devices, or at best on no more than two columns where the size of the devices was so small that they would present a small work area anyway.

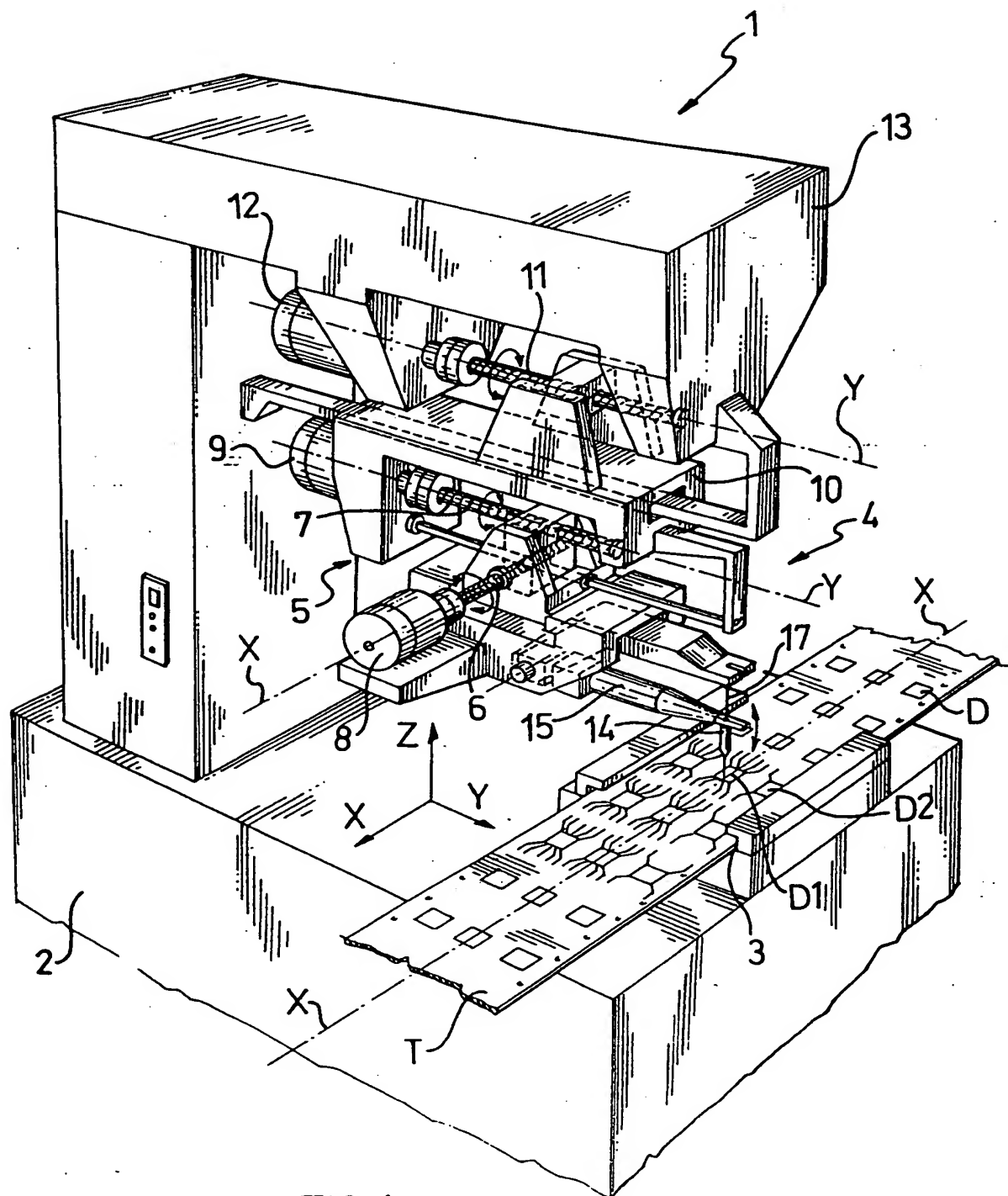
The invention, on the other hand, can operate on any number of side-by-side columns and devices of any size; in fact, the working range of the bonding head is not extended but merely shifted transversely. Thus, the number of the side-by-side columns can be selected contingent on other demands, e.g. to optimize such typical later processing steps as the pouring of insulating resin over the frame carrying the bonded devices.

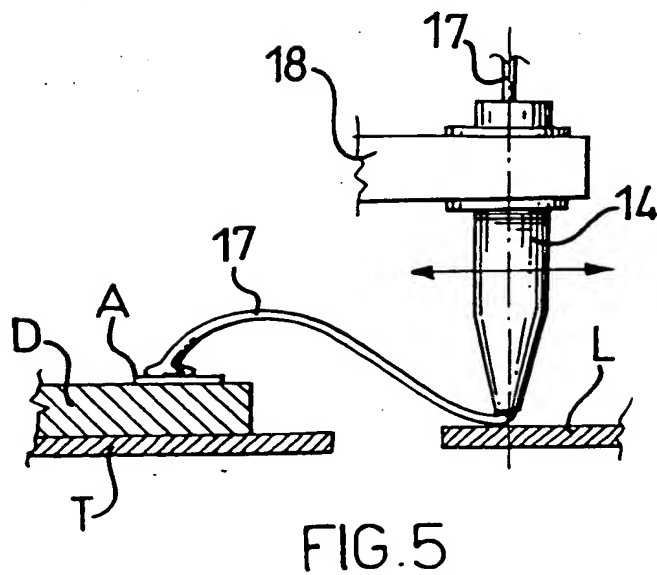
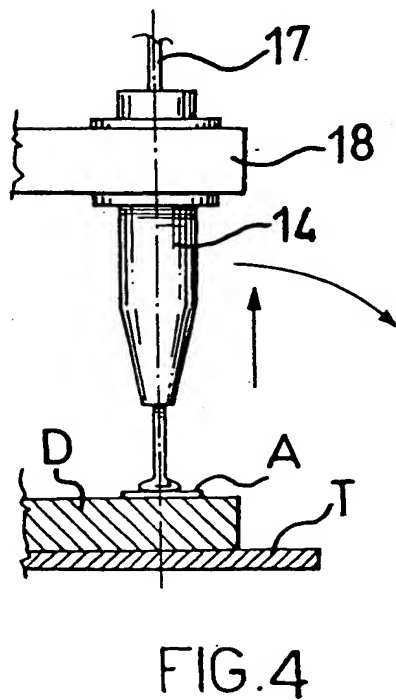
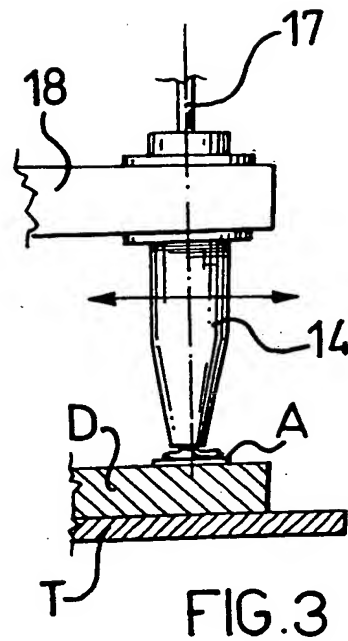
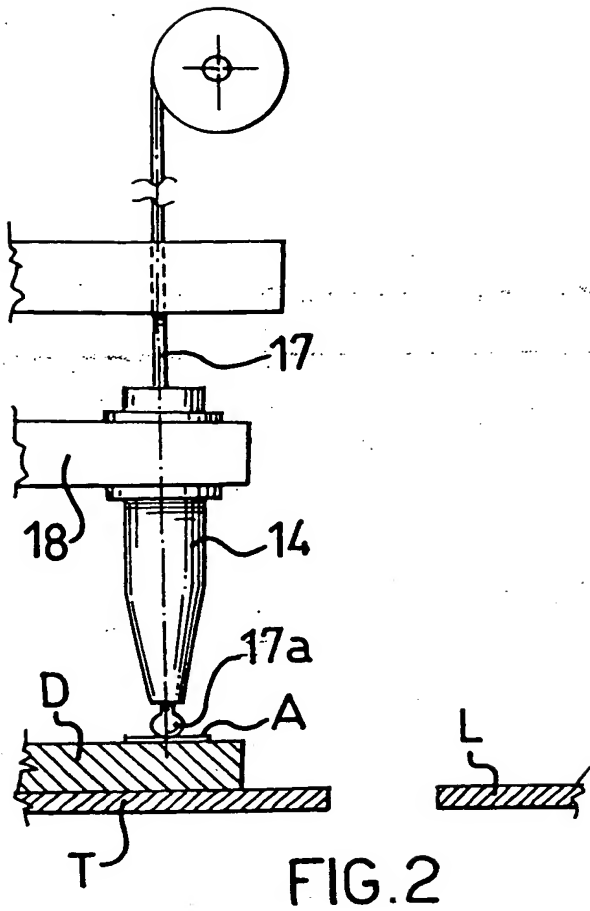
## Claims

1. A bonding apparatus for forming electric connections between predetermined bonding pads (A) of semiconductor electronic devices (D) and respective contact leads (L) formed on a frame (T) in which the devices (D) have been tidily arranged, comprising a supporting structure (2), means of advancing the frame (T) along a longitudinal direction (X) in a work plane (3) on the supporting structure (2), a bonding head (4), a high-precision X-Y table

(5) carrying the bonding head (4) for accurately setting the bonding head (4) in the work plane (3), characterized in that it further comprises a carriage (10) driven in a guided fashion across the supporting structure (2) in a transverse direction (Y) to the longitudinal direction (X), the X-Y table (5) being mounted on said carriage (10).

2. An apparatus according to Claim 1, wherein the carriage (10) is suspended from a portion (13) of the supporting structure (2) overlying the frame (T).
3. An apparatus according to Claim 2, wherein the X-Y table (5) is suspended from the carriage (10).
4. An apparatus according to Claim 1, wherein the bonding head (4) comprises a tubular bond bit (14), a feed channel (15) formed inside the bond bit (14), a bonding wire (17) being fed through the feed channel (15), elevating means (18) for moving the bond bit (14) vertically and pressing it onto the bonding pads (A) and the leads (L), and means of imparting ultrasonic vibration to the bond bit (14).
5. An apparatus according to Claim 4, wherein the elevating means comprises a swing arm (18) pivoted to the bonding head (4) and movable in a vertical plane, the bond bit (14) being mounted on one end of the swing arm (18).





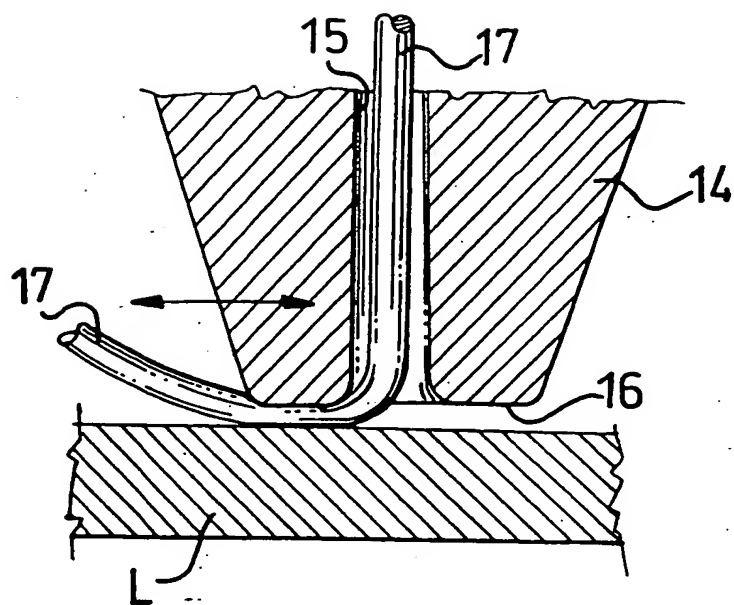


FIG. 6

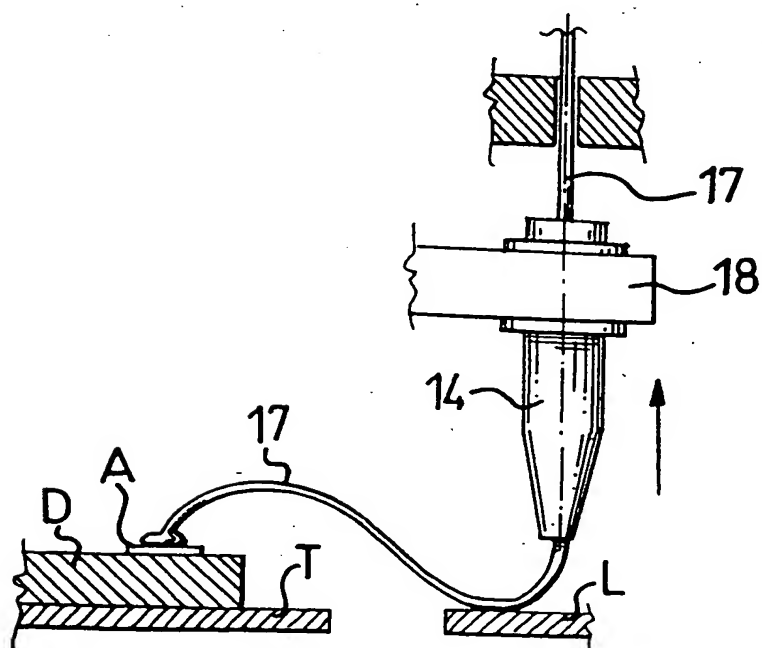


FIG. 7

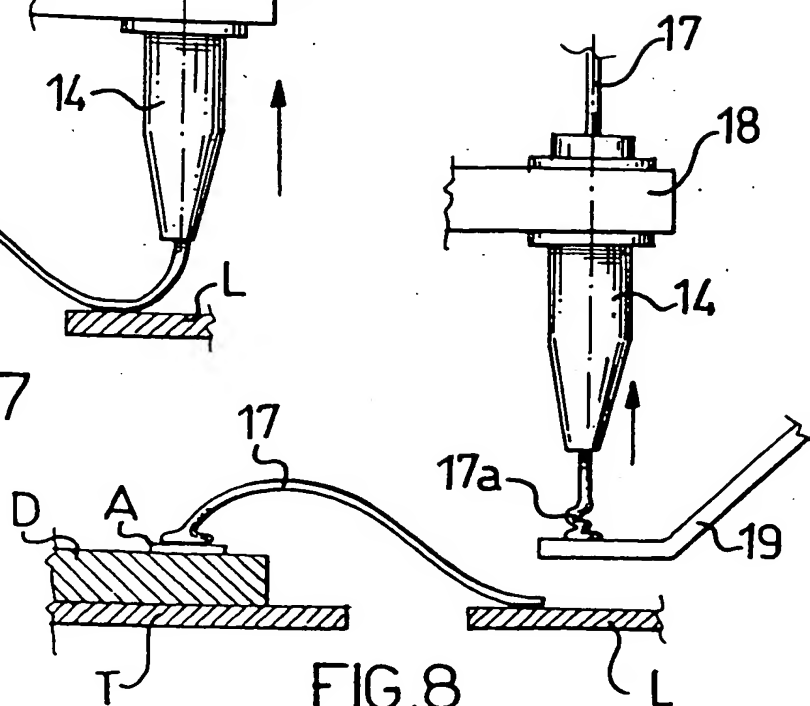


FIG. 8



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## EUROPEAN SEARCH REPORT

Application Number  
EP 94 83 0155

### DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	US-A-5 158 223 (SHIMIZU) * column 2, line 24 - column 4, line 34 * -----	1	H02B1/00 H01L21/00
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
			H01L B23K
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 12 August 1994	Examiner Bertin, M
<b>CATEGORY OF CITED DOCUMENTS</b> X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons ----- & : member of the same patent family, corresponding document			

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